SECTION I. INTRODUCTION

1.1 General

This handbook was prepared from the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC) technical memorandum X-53975. This memorandum was by McDonnell Douglas Corporation (MDC), Missile and Space Systems Division (MSSD).

1.2 Purpose

This handbook provides guidance in the design, manufacture, and quality control of FCC electrical interconnecting harnesses. Although this handbook is primarily for military applications, for both flight and ground support equipment, much of the information can be applied to commercial programs.

1.3 History

For many years, conventional round-wire cables (RWC) have been used for interconnecting components and electrical/electronic boxes in commercial, military, and scientific programs.

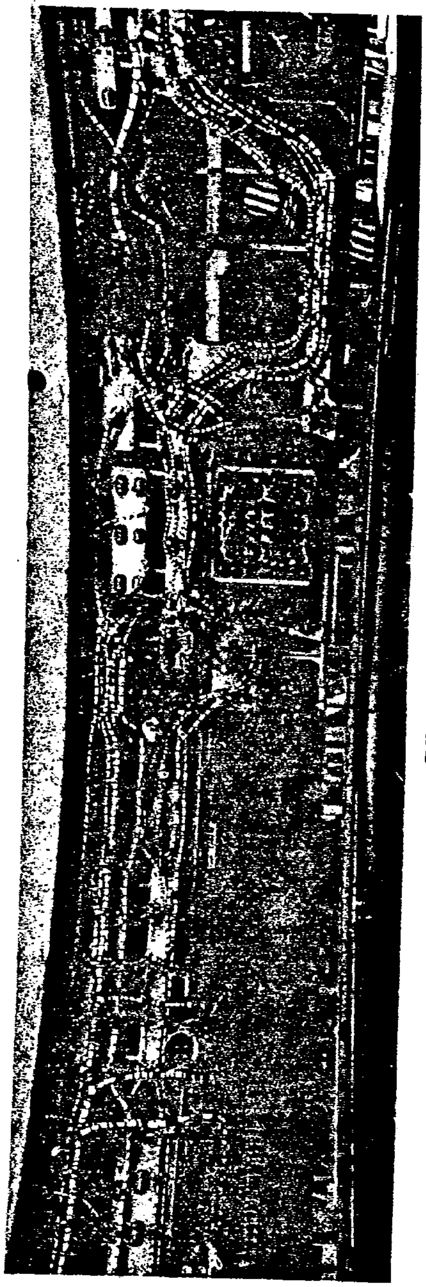
The 1950's saw the introduction of the rigid printed circuit (PC) board with its high packaging density, reduced costs, and improved reliability. The PC board provided the first significant step forward in the interconnection field. Its acceptance and success are now a legend.

Next came the flexible printed circuitry with solid rectangular conductors laminated between layers of high-performance insulation materials. This system is used extensively today for automobile dashboard wiring, computer section interwiring, and for many electronic packaging concepts used in space, missile, and aircraft systems. The flexible, printed-circuitry harnesses provide: reduced costs resulting from reduction of assembly times of up to 95 percent; major weight and space savings; and higher strength provided by the bonded, laminated insulating sheets, which in turn permits use of much smaller conductor cross-sections. Also, improvements in system performance and reliability are provided, resulting from the identity and repeatability of each harness and its installation.

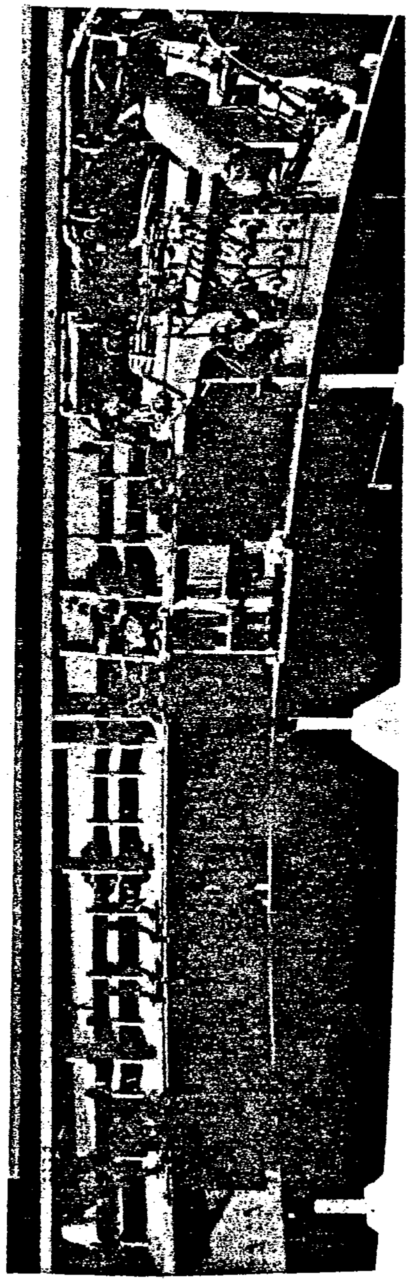
The use of continuous FCC to interconnect electrical/electronic units utilizing PC boards, flexible printed circuitry, and variations of these, logically follows the trend for improved interconnecting systems.

FCC development was begun in 1956 by the Army Ballistic Missile Agency at Redstone Arsenal, Huntsville, Alabama, in an effort to achieve weight and space savings, and increased reliability in rocket and missile cable systems. Effort has been continued by the same working group which has since been transferred to NASA/MSFC.

Figures 1-1 and 1-2 show the results of an FCC development study made by MDC for NASA/MSFC to determine the feasibility of using continuous FCC to interconnect electronic components in a modern space vehicle. The results of this study, an FCC applications study prepared by MDC for NASA/MSFC and other studies and applications indicate that the use of FCC offers many advantages in weight, space, cost, performance, and reliability for commercial, military, and space programs, for ground and airborne applications.



RWC INSTALLATION



FCC INSTALLATION

FIGURE 1-1. FCC versus RWC comparison, 180-degree section of Saturn S-IVB aft-skirt mockup.

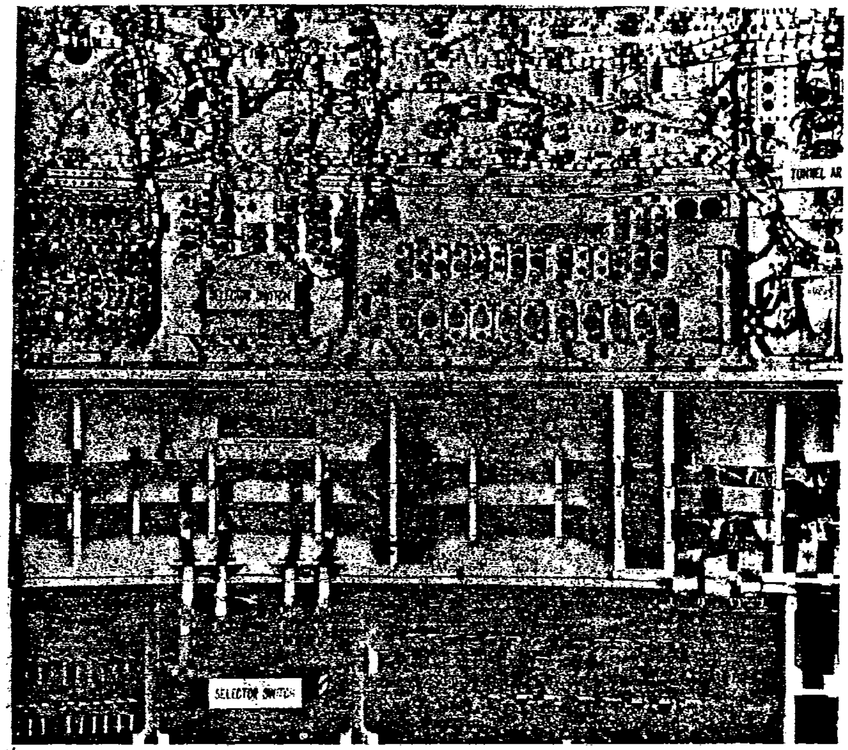


FIGURE 1-2. FCC versus RWC comparison, 60-degree section, Saturn S-IVB aft-skirt mockup.

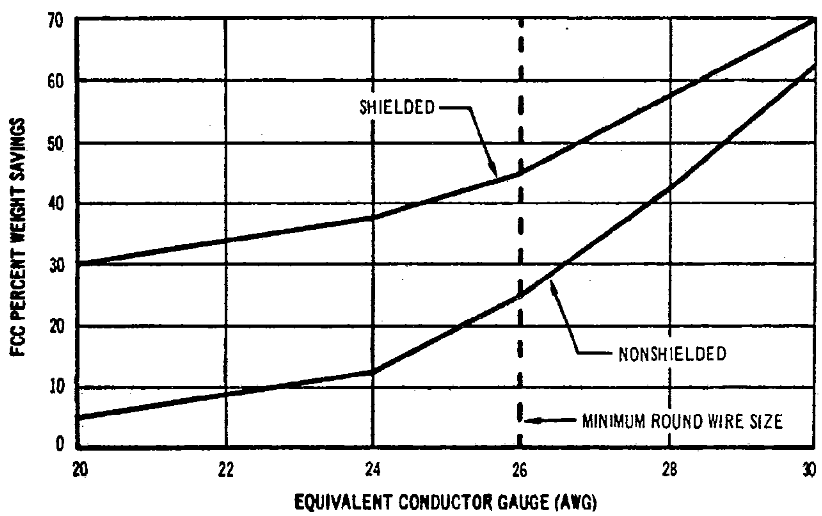


FIGURE 1-3. Weight-saving chart - FCC versus RWC.

1.4 FCC System Advantages

The FCC system offers appreciable advantages over the RWC systems in weight, space, and cost savings, as well as improved performance and reliability.

1.4.1 Weight Saving. From previous studies, the weights for FCC supports and clamps are considerably less than those used with RWC. This saving results primarily from cable stacking and simplification of clamping and supports for FCC. In addition, the NASA/MSFC conductor-contact connector system provides appreciable weight saving over the current miniature round connectors. However, the cable provides the major weight savings for the smaller conductors (Fig. 1-3). For comparison purpose, RWC per MIL-W-81381/2 with 7-mil H/film insulation and alloy conductors, and FCC cable per MIL-C-55543 were considered. High-density FCC was used for 20 and 22 equivalent AWG sizes. The FCC weight saving increases as the conductor cross-sections decrease. Future programs, with integrated circuit electronics, can be satisfied with wire-gauges of 26 and smaller in many circuits.

1.4.2 Space Saving. Figure 1-4 shows the space savings that can be achieved through the use of FCC. The areas compared are for typical interconnecting harnesses requiring three separate bundle runs. The 80 to 90 percent space savings shown are particularly advantageous in tunnel and other congested areas where a minimum height is available for harness runs. Major connector mounting-and-handling installation area savings are achieved by the FCC connector system. Figure 1-5 shows the area configurations, and Figure 1-6 shows the actual mounting and handling area required.

1.4.3 Cost Saving. To arrive at realistic cost comparisons, the cost of materials, design, development, harness fabrication, and installation must be considered. Table 1-1 lists these comparisons developed and verified by subsequent studies, and those performed by other agencies. The saving percentages shown are average and can vary from program to program. However, the 80 percent shown for recurring harness fabrication is realistic for all programs utilizing properly designed FCC systems.

TABLE 1-1. COST COMPARISON - FCC VERSUS RWC SYSTEMS

Item	Sub-item Percentage Of Major Item	FCC Cost Saving (%)[a]	
		Sub-item	Major Item
Engineering			-5
System	25	-10	
Harness Layout	25	-10	
Production Drawings	25	0	
Schematics, etc.	25	0	
Development			20
Materials			28
Cable	40	0	
Connectors	40	35	
Clamps	5	50	
Supports	15	75	
Harness Fabrication			80
Harness Installation			40

a. To realize the cost savings indicated, FCC must be applied early in the program to eliminate redesign, redevelopment, and requalification.

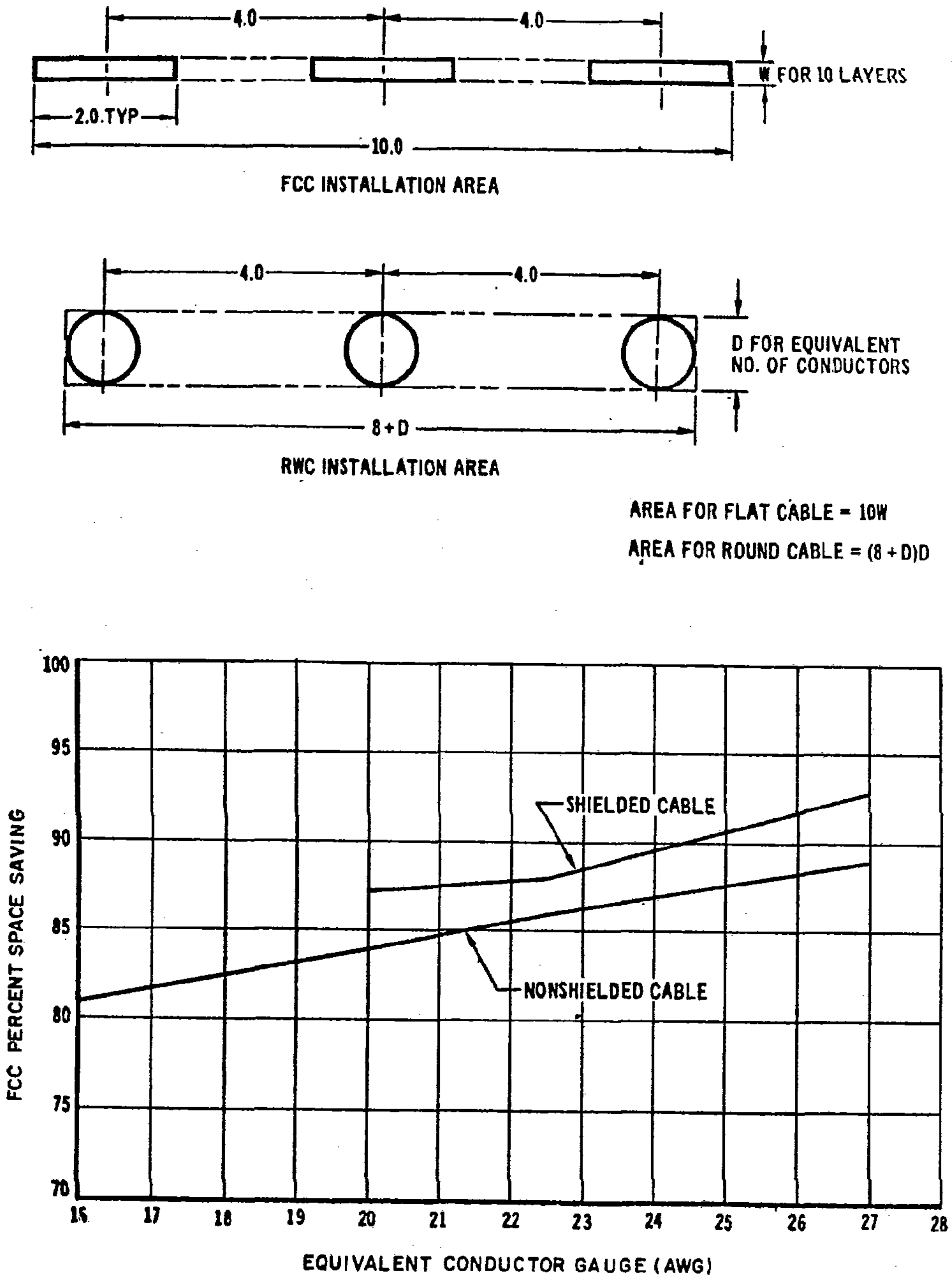
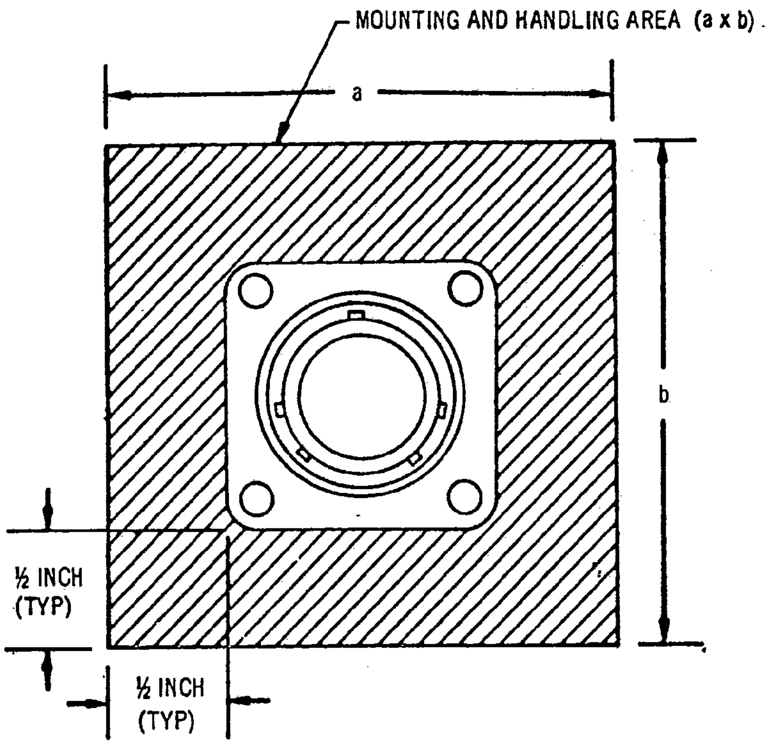
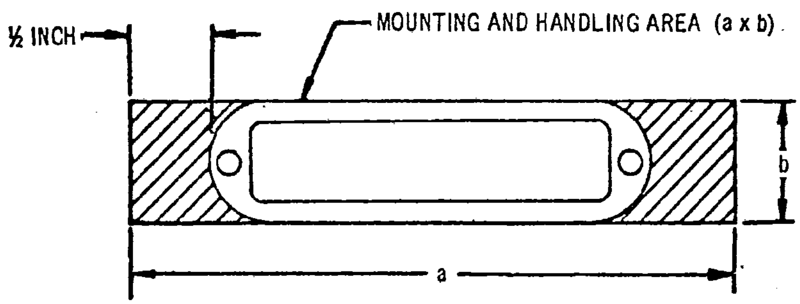


FIGURE 1-4. Space saving - FCC versus RWC.



RWC RECEPTACLE



FCC RECEPTACLE

FIGURE 1-5. Mounting and handling area configurations.

ROUND CONNECTORS	CANNON PV SERIES SHELL NO.	10	14	16	20	22	24	
	NUMBER OF PINS	6	12	26	39	55	61	
FCC CONNECTORS	NUMBER OF PINS	*6	*12	24	36	50	64	76

*NOTE: THESE CONNECTORS USE ROUND SHELL SIZES EQUIVALENT TO THOSE ABOVE.

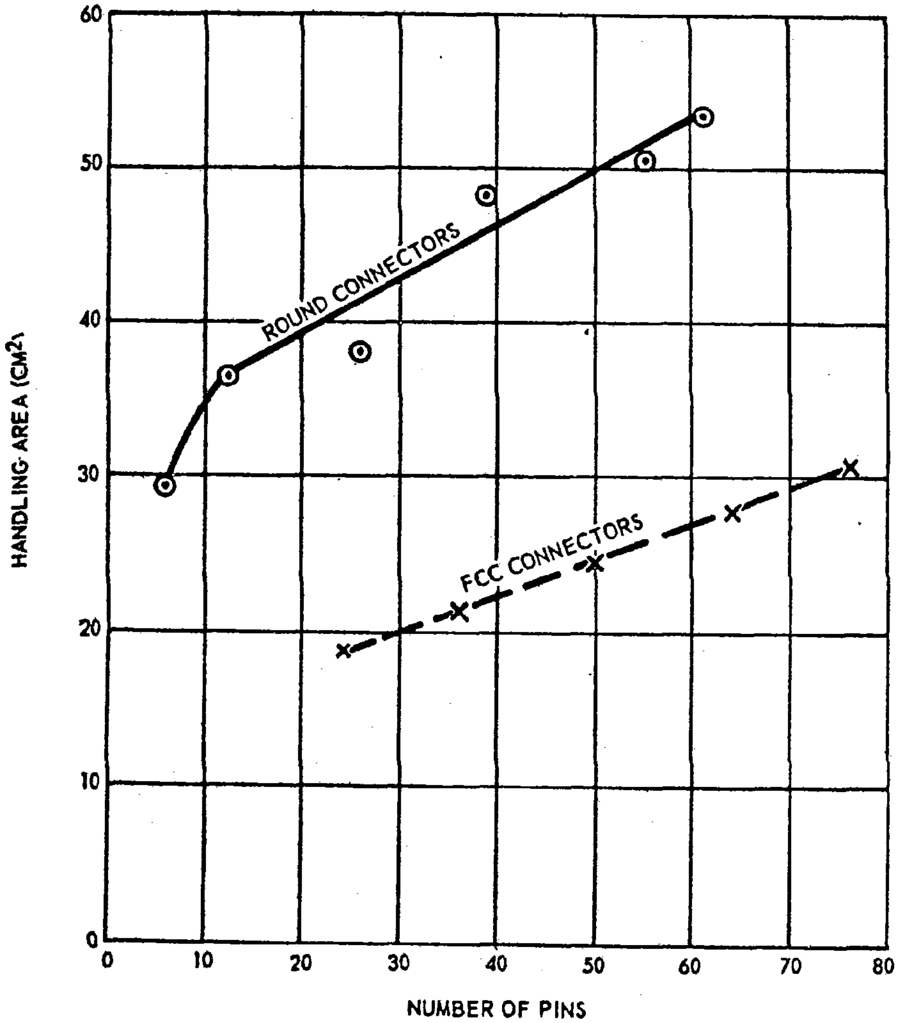


FIGURE 1-6. Mounting and handling area - FCC versus RWC connectors.

Figure 1-7 shows the cost comparison between FCC and RWC. The cables considered were the same as those used for the weight-saving comparison of Paragraph 1.4.1. The connector cost saving of 35 percent (Table 1-1) results primarily from the use of the NASA/MSFC molded-on plug assemblies.

1.4.4 Increased Thermal Capacity. Tests conducted by NASA/MSFC on both FCC and RWC equivalent bundles under ambient and vacuum conditions disclosed major thermal advantages for the FCC. The current-carrying capacity may be uprated for FCC for the same conductor cross-section as follows:

FCC Cable Configurations	Uprating Factor In Air	Uprating Factor In Vacuum
Single-Layer	1.50	1.55
Three-Layer	1.35	1.50
Ten-Layer	1.05	1.05

These tests, which are based on many electrical measurements, confirm the increased current-carrying capacity, or decrease in operating temperature, when equivalent conductor cross-sections are applied to the same electrical loads.

1.4.5 Improved System Performance. Major advantages in system performance can be realized through the use of FCC. The interconnecting harnesses can be designed for the required electrical characteristics that are predictable and repeatable. The control of the conductor cross-sections, their location in relationship to adjacent conductors, and the registration control of each cable in the interconnecting harness-runs provide the required system performance and assure repeatability from unit to unit.

1.4.6 Increased Reliability. The use of FCC for interconnecting harnesses provides increased reliability in a number of specific areas. The high tensile strength of the insulation layers and cable construction, which provides mechanical load-sharing, provides a major increase in effective strength. The percentage increase becomes even greater in the small conductor sizes. The abrasion resistance is greatly improved as a result of the geometry of the harness cross-section. The mechanized FCC termination system, made by cable layer, is simpler and more reliable, and quality control is much simpler. The FCC harness assemblies are simpler, lighter, and require less space. The improved heat dissipation assures lower operating temperature. System performance is improved as described in Paragraph 1.4.5.

1.5 Present Status of FCC

1.5.1 Specifications. Military specifications (MIL-C-55543 and MIL-C-55544) have been prepared and released for FCC and FCC connectors by the tri-service government agencies. Their issuance provided the program authority and the vendor guidance so badly needed in the past.

1.5.2 Available Hardware. Numerous manufacturers are currently making, or capable of making, FCC in accordance with the requirements of MIL-C-55543. Testing on typical, available cable has indicated that the specification requirements can be met. A complete line of conductor-contact connectors per MIL-C-55544 has been developed by NASA/MSFC. Tooling has been completed, and testing has been accomplished. Prototype samples of the pin-and-socket specification connector are currently undergoing evaluation testing. An FCC-to-RWC transition has been developed, tooled, and tested for use on the NASA/MSFC ATM program. Other wire-change devices, clamps, and supports have been developed for FCC use. All of the above are defined and further explained in Section II.

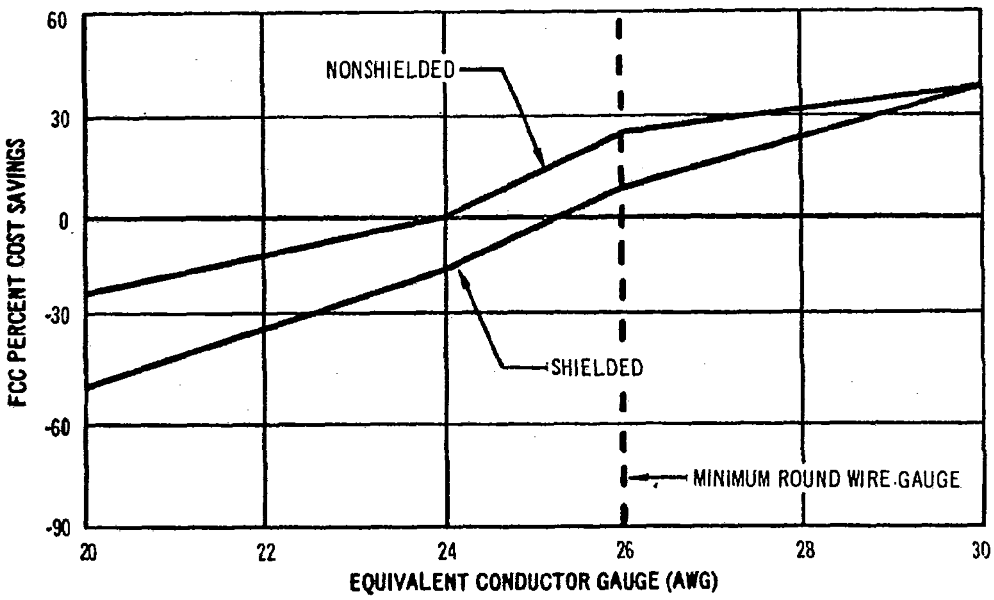


FIGURE 1-7. Cable cost saving — FCC versus RWC.

1.5.3 System Studies. MDC performed a development study and an application study for NASA/MSFC to determine the feasibility of applying FCC to a large missile stage.

The MDC Aircraft Division in St. Louis has prepared the functional FCC mockup shown in Figure 1-8. FCC was used to interconnect analog, digital, and high-frequency communication systems. Over 75 percent of the existing RWC shielding was eliminated, with a system performance equal to or better than that of the original RWC harnesses.

Lockheed Aircraft Corporation performed a similar study to determine the feasibility of using FCC harnesses in existing military aircraft. Their study indicated major weight and cost savings for the FCC system.

1.6 Predicted Future Use

The many advantages of the FCC system assure its increased use on future programs. Data from surveys made by various government, other prime contractor, and component manufacturer estimates indicate extensive use of FCC in the future.

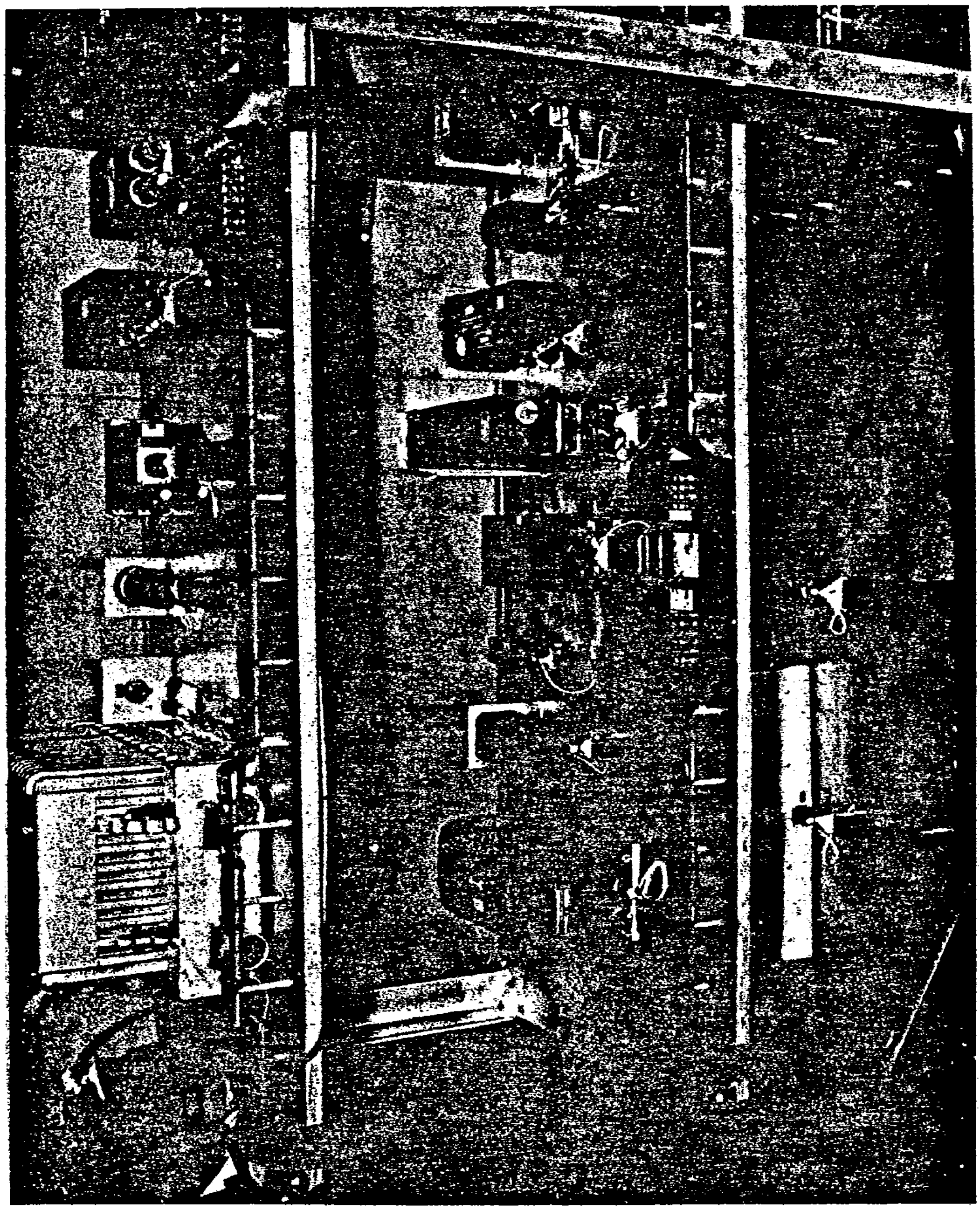


FIGURE 1-8. FCC harness installation for aircraft application evaluation (MDC).

1.7 Report Format

This handbook is divided into coordinated sections to provide the continuity required for overall FCC application. These sections are as follows:

Section I - Introduction and Familiarization

II - Hardware

III - Design Application

IV - Wiring Changes

V - Reliability

VI - Manufacturing and Installation Techniques

VII - Quality Assurance - Inspection and Test Procedure

The material presented covers the definition and application of current FCC systems including the NASA/MSFC and other conductor-contact connector systems and the pin-and-socket contact connector systems.

1.8 Trade Names

It is not the intent of this handbook to endorse trade names. Those materials referenced herein, with manufacturer's name and trademark, are well suited for the particular applications specified. The use of these materials should not be limited to the trade name used, provided other materials of equal quality, and suited to the particular application, are available.